US EPA Administrative Order on Consent
Article IV.G.2

2017 EGCS PH and Flowrate Report – Deviation Analysis

Part (2)

IV.G.2. 2017 EGCS pH and Flowrate Report – Deviation Analysis

"The 2017 EGCS pH and Flowrate Report shall also identify and analyze the root causes of any VGP pH exceedances identified in Section G.1 above, providing: 1) Carnival's conclusions regarding the factors that result in VGP pH exceedances; 2) the length of time the different factors would be expected to occur in any given day/week/month/season; 3) Carnival's actions to address each cause of VGP or 2017 Interim Effluent pH exceedance; and, 4) Carnival's recommendations on how any of these factors might be addressed in the future."

Discussion: The pH exceedance summaries and analyses for each ship in Alaska during the 2017 season are provided in the slides provided separately in electronic powerpoint file AOC IV.G.2. Part 1. An initial summary of the most common factors for pH exceedances and related notes related to items 1-4 above follow:

1. **Some factors resulting in VGP pH exceedances include**:

a. Sensor issues, or sensor calibration checks by crew.

b. Low buffering water flow rates.

c. System transitions or fluctuations, driven by engine starts/stops or engine load changes, and seawater flow rate changes driven by gas analyzer fluctuations.

d. Areas of lower ambient pH seawater, not unusual in southeastern Alaska waters.

e. Not determined issues.

2. **Length of time each may typically occur**:

a. Low buffering flow rates are being seen for extended periods, but primarily on two ships.

b. Dependent on geography, such as the proximity of rivers and/or enclosed waters, low ambient pH seawater may be experienced for a few minutes to a few hours in transit, and 8 or more hours for a ship in port (e.g. Skagway).

c. Though unpredictable, the instrument anomalies not associated with any system changes seem to typically be of short duration, typically from 3 to 9 minutes.

d. System fluctuations may be persistent but typically we are seeing the sensor readings return to steady state within 15-30 minutes of a significant change.

e. Crew calibration checks appear to typically last from 3-9 minutes, depending on whether they are using the 4.0pH test fluid only, or also the 7.0pH fluid.

3. **Actions taken to address causes of pH exceedances**:

During the 2016-17 Alaska off-season Carnival:

a. Installed increased capacity buffering water systems on all 15 ships planned for the 2017 Alaska season, plus a number of other ships operating from US ports. These modifications typically increased buffering flow rate by 50%, from 800 to 1200-1300m3/hour. These typically included larger buffering pump motors (from 47 kw to 75 or 90kw), larger frequency drives, larger static mixers, and larger buffering system piping.

b. Contracted with fuel distributors in Seattle and Vancouver to provide 2.0% sulfur fuel for all Carnival group ships the full 2017 Alaska season.

c. Installed new pH meters in the seawater inlet sensor racks ("Rack 1") in all planned Alaska ships, and Ecospray technicians developed and installed the software to integrate these into automation and into the onboard Compliance Computer (and Compliance Report), adding columns for the new Rack 1 pH meter reading and the inlet vs. outlet pH differential, and incorporating into the alarms logic.

d. Calibrated or recalibrated all the new and existing pH meters in planned Alaska ships, using qualified technicians from instrument and EGCS makers.

e. Trained more than 150 ships engineers and environmental officers at the EGCS Course at Carnival's training center in Almere, Netherlands.

4. **Recommendations how these factors may be addressed in future**.

Carnival has five recommendations to reduce the number of pH exceedances while continuing to increase EGCS usage rates of EGCS on ships in VGP waters, both in Alaska and all other US waters:

a. Provide additional system status dashboards for enhanced onboard monitoring of critical EGCS parameters by ship's staff, in both the ECR and Bridge. **(Planned).**

b. Provide EGCS dashboards for the new Carnival Fleet Operations Centers in Seattle and Miami, to allow 24/7 external monitoring of key parameters, especially for ships in VGP waters. **(In progress).**

c. Complete automation software change to support the new fleet-wide standard of EGCS start before engine start, to reduce pH exceedances due to delays in instrument readings. **(In progress).**

d. Complete automation software change to allow the buffering water to constantly attempt to achieve the pH regulated limit for the operating area. Until then, re-brief all ships of the requirement to operate all buffering pumps at 100% in VGP waters. **(In progress).**

e. Submit a change proposal to US EPA for adjusting the VGP rule for discharge of EGCS washwater to 5.5pH at point of discharge. **(Planned).**

"In addition to any other factors identified by Carnival, this analysis shall discuss:

IV.G.2.a.

> **"Characteristics of voyages in Alaskan waters that make them unique with respect to control of sulfur emissions and pH in effluent discharges, including temporal and geographic implications and whether these challenges exist for the entire duration or only at specific points during the voyage (*e.g*., when located within the U.S. ECA; within waters of the U.S. subject to the VGP; or near a particular city, water body or freshwater influx)."**

Discussion: Alaska cruises are heavily concentrated in Southeastern Alaska and are close to land (and within 3nm, or VGP waters) for a high percentage of the time. Most cruises originate in either Seattle or Vancouver and are within the North American ECA (Emission Control Area) the entire voyage, including the transits through Canadian waters to/from Alaska. Once arriving in Alaska waters and the Inside Passage, the cruise itineraries are frequently passing the mouths of rivers and almost all ports visited are also located at the mouths of rivers.

The spring snow melt in Southeast can start as early as April/May and continues through the summer season, increasing river volumes and lowering the pH of river waters, due to the lower pH of the snow pack. This can create lower pH (< 8.2 pH) zones near mouths of rivers and which may be influenced by currents and encountered by ships passing further away as well and is largely unpredictable.

As the efficiency of the Exhaust Gas Cleaning Systems (EGCS) is linked to the alkalinity of the ambient seawater surrounding the ship, as the seawater pH falls below 8.2 progressively more volumes are needed for SO2 removal by the system. Larger volumes of buffering water are also needed for mixing with that washwater to reach an overboard discharge level of 6.0pH, as required within VGP waters (within 3nm of US coastline).

In restricted or partially enclosed waters with rivers, such as Taiya Inlet Canal leading to the port of Skagway, relatively limited mixing with outside seawater means a generally lower ambient seawater pH, and this leads to higher volumes of seawater needed for EGCS operations. This is not normally a problem for SO2 removal, but can be challenging for onboard pH buffering to reach the overboard discharge pH requirement of 6.0.

IV.G.2.b.

"Characteristics of normal vessel engine operation (*e.g.,* engine power, engine load, startup/shutdown, fuel changeover), situations that may warrant deviations from those normal operations, and how these operations affect EGCS operation and EGCS washwater discharges. This shall:

i. Include information on the procedures/timing/concerns with fuel changeover (from low sulfur (0.1%) to high sulfur fuel and vice versa) during a voyage, whether for technical or operational reasons."

<u>**Discussion:**</u> The changeover from one fuel to another onboard cruise ships is not automated and requires close management by experienced engineer watchstanders. Changeover time from HFO to MGO requires time; an experienced engine room team can effect a basic changeover on an engine in about 45 minutes when the DG load is in a range of 70-85%. More time is needed at lower DG loads, which are common in Alaska operations. A strict protocol controlling a measured transition is required, due to differences in fuel viscosity and lubricity between HFO and MGO. Some ships have additional fuel modules installed which can allow more flexibility in the process by switching to engines already connected to a second fuel source, but these are expensive modifications and not standard in all ships. The Engineer must also always consider maintaining redundancy of his plant through use of engines in different engine rooms, as well as the limits on his flexibility for DG (diesel generator) and main switchboard combinations. As in Alaska the ship is usually operating close to land, day and night and in all weather situations, any problems in switching fuels that can lead to loss of power is a significant safety concern and such transitions should be minimized.

ii. "Explain situations when pH fluctuations are caused by vessel operations other than the unique concerns presented by buffering in Alaskan waters (*e.g.*, change in engine power, switching engines, multiple engines in use, startup/shutdown, *etc.*), as well as when and how these pH fluctuations from vessel operations may contribute to exceedances of the VGP or 2017 Interim Effluent pH limits for EGCS discharges and the actions taken by Carnival to prevent VGP and 2017 Interim Effluent pH exceedances resulting from these fluctuations."

<u>**Discussion:**</u> pH fluctuations have been experienced in several situations apart from low pH of ambient seawater, as mentioned above, and include:

a. Changes in engine load, which are followed by changes in SO2/CO2 ratio as measured by the installed gas analyzer. The system automation then adjusts the seawater supply flow rate, which affects the pH level of the washwater leaving the scrubber tower, which may not be fully compensated by the current buffering water volume and can lead to temporary exceedances from the limits. The risk of exceeding pH is increased with rapid engine load changes (such as in maneuvering), and where safely practical more gradual changes will lower this risk.

b. Start-up of engines, which is normally accompanied by simultaneous EGCS start to minimize the time delay to reach accurate sensor readings. The automation will react to the engine load increase from zero by starting the EGCS Seawater Pump, but the pump acceleration curve (designed to avoid too rapidly filling of the scrubber tower and potential flooding) will always lag the engine power increase, creating a short delay in reaching full accurate readings from both the air and water instruments, including potential for pH exceedances from limits. Starting EGCS units 10-20 minutes before engine start may achieve sufficient seawater flow to settle instruments and is now being incorporated into automation for use as the new standard procedure, whenever practical.

c. Multiple engines/EGCS, which can create seawater demands near the capacity of the seachest and/or seawater supply and buffering manifolds. This is not usually a problem in ECA operations outside VGP waters, even when higher ship speeds and the need for more engines on line is more common, because the requirement for buffering water is significantly less outside VGP. In VGP waters, however, the requirement for buffering water volumes is normally at the system limits even with two engines on line, and with additional engines the EGC systems may not have enough buffering water to maintain VGP pH discharge limits. When multiple engines are required, when practical the use of lower engine loads may reduce seawater demand.

d. High engine loads, especially loads above 80% will require high seawater flow rates for washwater and this in turn may exceed the capacity of the buffering pump to achieve a commensurate increase in buffering seawater to maintain the system within discharge pH limits.

e. Higher sulfur content in fuel will require more seawater flow to remove and therefore higher buffering flow rates than the system can provide in VGP waters. To mitigate this, Carnival has contracted with fuel distributors in Seattle and Vancouver for fuel with 2.0% limits on sulfur content.

iii. "Explain the relationship of the quantity of buffering to the pH of the washwater discharge. "

Discussion: As pH is a logarithmic scale, the quantity of buffering water needed to raise the pH of a volume of water is significantly more between 5.5 -- 6.0 pH than between 5.0 – 5.5pH.

For example, in a 12MW engine using 2.0% sulfur fuel at 70% engine load and with 8.2pH ambient seawater, a washwater flow rate of 450m3 may achieve an SO2/CO3 ratio of 3.5 and an overboard discharge pH of 5.5 with 500m3 of buffering water.

However, to reach an overboard discharge of 6.0pH the same situation is likely to require 1100-1200m3 of buffering water, roughly 3 times the amount of washwater.

Although there are titration tables available to predict these volumes and outcomes, none have been found accurate enough in practice and this data must be gathered empirically across many ships.

IV.G.2.c.

> **"Challenges with use of continuous pH monitors to demonstrate compliance with the VGP's EGCS pH limits (*e.g.*, equipment calibration, false readings, operator/maintenance error, equipment malfunction, *etc.*) and how those challenges relate to demonstrating compliance with pH limitations. This shall:**
>
> > **i. Include a discussion of how Carnival will identify and document pH readings in its data that do not accurately reflect the pH of the effluent being tested (*e.g.,* calibrations, false readings, malfunctions, *etc.*)."**

<u>Discussion:</u> The installed pH meters in use by Carnival are from two of the largest suppliers of such instruments to industry: Hach-Lange (mostly) and Endress Hauser. These carry a maker's recommended calibration period of 2 years, but we calibrate annually to meet VGP requirements. Calibration is done by outside technicians from the instrument maker or EGCS systems maker that visit the ship for this purpose; ship personnel do not calibrate but are experienced in checking calibration and they have the test fluids onboard for this purpose. These instruments are delicate and work best in continuous service with routine cleaning, but the readings can be affected by:

a. dirt or other substance on the sensor

b. improper handling or sensor cleaning with wrong materials

c. dry periods when not constantly immersed in water

d. gas or bubbles in the water that may settle around the sensor tip

e. calibration errors

f. temperature changes, to a lesser extent.

We do also see:

- Sudden pH changes to 4.0 or goes up to 7.0, which are the pH levels of the calibration check fluids, and indicate that crews may be checking the sensor calibration.
- Instrument anomalies, brief periods of excursion from steady readings in a steady-state system, which may indicate passing influence of some impurity or bubbles on the sensor but are generally unexplained by the other system parameters.

Over time we have seen improved reliability of these sensors as our training levels and experience with them has increased, and outright sensor failures are no longer common, but anomalies are still present.

As shown in Part 1 of this Deviation Analysis Report, we are able to isolate and evaluate non-compliant pH records on an ongoing basis through the Neptune data flow available from most EGCS ships.